DIURNAL DISTRIBUTION OF RAINFALL AT ST. JOSEPH, MO., APRIL TO OCTOBER

By W. S. BELDEN

[Weather Bureau, St. Joseph, Mo., June 1936]

The average annual precipitation at St. Joseph, Mo., as recorded during the years 1910 to 1934, inclusive, is 34.28 inches. Of this amount 26.63 inches, or approximately 78 percent, occurs during the 7 months April to October, inclusive. June and September are the wettest months with averages of 5.03 and 5.02 inches, respectively; while July is the driest summer month with an average of 3.03 inches.

Table 1 gives the normal rainfall by decades and months, April to October, based on the observations over the 25-year period. It will be noted from this table that there is a gradual decrease in rainfall during June and July from a maximum of 2 inches in the first decade of June to a minimum of 0.88 inch in the last decade of July. A secondary maximum of 1.95 inches appears in the middle decade of September, followed by decreasing values with only 0.63 inch in the closing decade of October.

Table 2 gives the percentages of the total rainfall that occurred during the daytime and during the nighttime.[1] Figure 1 shows graphically the values given in table 2. The table and figure present conclusive evidence that nighttime rain is considerably greater in total amount than daytime rain. In July the contrast is greatest, with with about two-thirds of the total July rainfall occurring in the 12-hour period 7 p. m. to 7 a. m. Sixty percent of the rainfall for the 7 months' period occurs during the nighttime and 40 percent during the daytime. On the average the rainfall occurring within the 3-hour period ending at 5 a. m. is more than two and one-half times greater than that falling within the 3-hour period ending at 2 p. m. The hour ending at 4 a. m. has the greatest hourly rainfall, and the hour ending at noon the least.

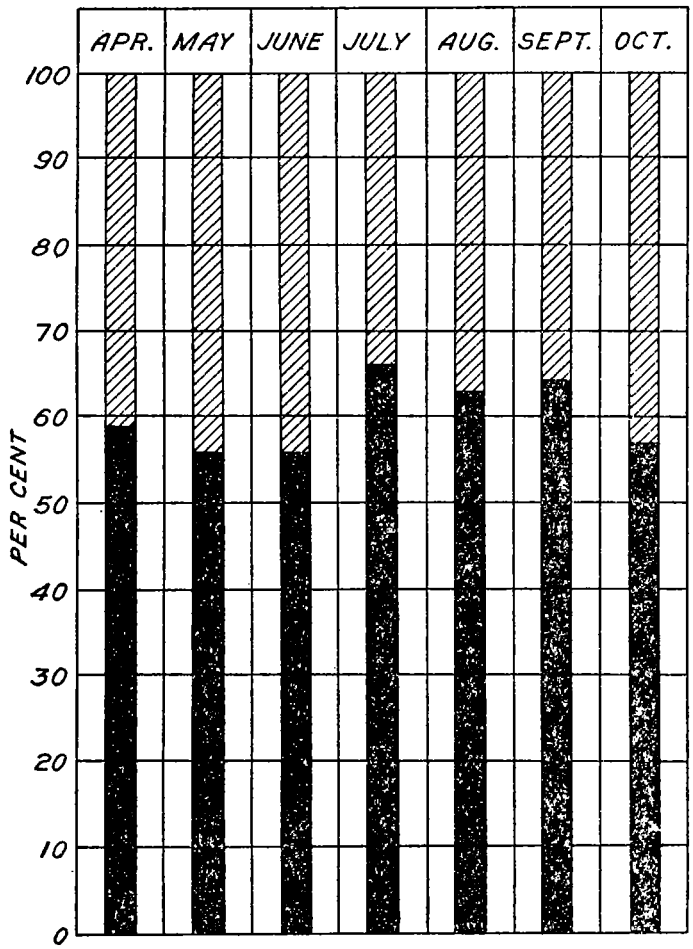

FIGURE 1.—Percentage of the total rainfall occurring at night (7 p. m. to 7 a. m.) and during the day (7 a. m. to 7 p. m.), April to October, inclusive, 1910-34. Solid shading indicates nocturnal percentages (90th meridian time).

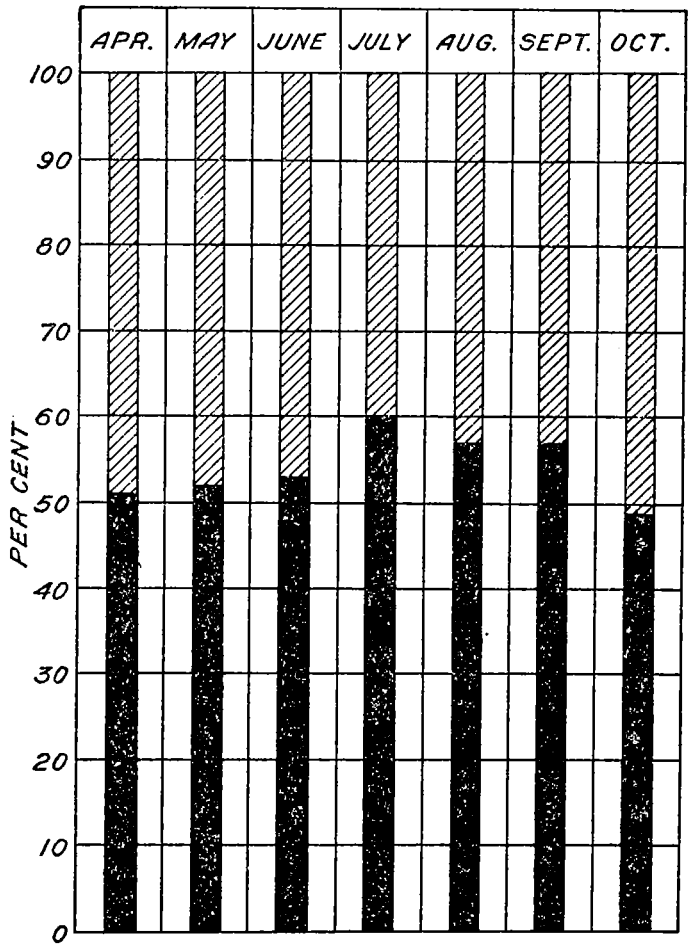

FIGURE 2.—Percentages of total duration of rain occurring at night (7 p. m. to 7 a. m., solid shading) and during the day (7 a. m. to 7 p. m.), April to October, inclusive, 1910-34.

The time during which rain falls is longer at night than during the day, but the difference is not so pronounced as in the case of the amounts of rainfall. Table 3 gives the monthly total duration of daytime and nighttime rainfalls for the 25-year period, and figure 2 shows the percentages graphically. Daytime and nighttime durations are almost equal in April and October; but in the other 5 months, May to September, nighttime rains are more prolonged than daytime rains. In July 60 percent of the total duration of rainfall occurs during the nighttime. The average monthly duration of daytime rains decreases from 33 hours 56 minutes in April to 10 hours 56 minutes in

[1] The terms "day" and "night" as used in this paper, unless otherwise indicated, have reference to the periods from 7 a. m. to 7. p. m. and from 7 p. m. to 7 a. m., respectively, 90th meridian time; the division points correspond to the hours of the regular twice-daily observations at the regular Weather Bureau stations.

July. Nighttime rains during these 4 months, April to July, also have a similar gradual but less marked decrease in duration. In August and September there are corresponding increases in duration of both daytime and nighttime rains, and the increase in duration of daytime rains continues through October.

Table 4 shows the average duration of rains that begin during each hour of the day and night, and table 5 shows the average duration of rains that begin in the daytime and in the nighttime. For the season April to October, inclusive, as a whole, the average duration of rains beginning between 7 a. m. and 7 p. m. is 2 hours 44 minutes; and between 7 p. m. and 7 a. m., 3 hours 57 minutes. Rains beginning within the 5-hour period 8 p. m. to 1 a. m. have an average duration of 4 hours 42 minutes, while rains beginning within the 5-hour period 9 a. m. to 2 p. m. continue on the average 2 hours 47 minutes. Rain beginning between 9 p. m. and 10 p. m. continues for a considerably longer period than rain beginning in any other hour. This is particularly noticeable in the months of April, May, and September. In July rains starting in the nighttime have an average duration of 2 hours 47 minutes as compared with an average duration of 1 hour 23 minutes for rains starting in the daytime. The average length of April rains is 4 hours 28 minutes, while the average length of July rains is 2 hours 5 minutes.

Beginnings and endings of all rains were used in the determination of durations; and when not definitely known they were approximated.

Figure 3 shows the average hourly intensity of rainfall for the season, April to October, inclusive, for the years 1910 to 1934. The intensity increases quite decidedly from 8 p. m. to 10 p. m., after which there is rather a sharp decline to 11 p. m., followed by another increase. The intensity is relatively high during the 5 hours beginning at midnight, while the lowest rate of fall and the lightest hourly amount occur from 11 a. m. to noon.

As pointed out by J. B. Kincer,[2] the distribution and duration of precipitation have an important bearing on agriculture. This study of the precipitation records for St. Joseph, Mo., shows that Nature provides much the greater portion of the rainfall during the warm growing season, and that there is a marked variation in its diurnal distribution, with the greatest concentration of rainfall during the nighttime. In the harvest and threshing period, daytime rains are comparatively infrequent, which is an economic factor of much importance. Nighttime rains occur over a longer period of time and in more generous amounts, thus materially increasing the beneficial effects of rainfall on vegetation.

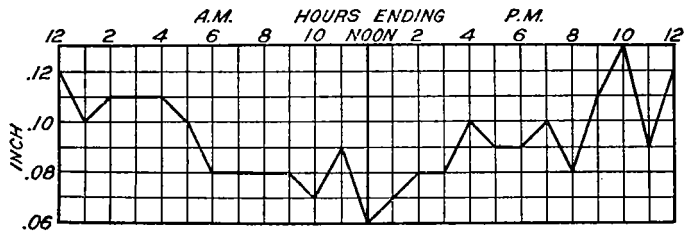

FIGURE 3.—Average hourly intensity of rainfall for the season, April-October, at St. Joseph, Mo. (total hourly accumulated divided by the number of times measurable rainfall was recorded, 1910-34.

TABLE 1.—*Normal rainfall at St. Joseph, Mo., by decades and months, April to October, as determined from records for the years 1910 to 1934 inclusive*

Period	April	May	June	July	August	September	October
	In.	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*
1st decade	0.99	1.11	2.00	1.12	1.30	1.67	1.17
2d decade	1.40	1.32	1.58	1.03	1.31	1.95	.89
3d decade	.82	[1] 1.56	1.45	1.88	[1] 1.05	1.40	1.63
Monthly	3.21	3.99	5.03	3.03	3.66	5.02	2.69

[1] For 11 days.

TABLE 2.—*Percentage of total rainfall at St. Joseph, Mo., occurring during the 12-hour periods 7 p. m. to 7 a. m. and 7 a. m. to 7 p. m., April to October 1910 to 1934 inclusive*

Month	7 p. m. to 7 a. m.	7 a. m. to 7 p. m.	Month	7 p. m. to 7 a. m.	7 a. m. to 7 p. m.
	Percent	*Percent*		*Percent*	*Percent*
April	59	41	September	64	36
May	56	44	October	57	43
June	56	44			
July	66	34	Average	60	40
August	63	37			

[2] *See* Monthly Weather Review, 1921, 49:350.

TABLE 3.—*Monthly total duration (in hours and minutes) of daytime and nighttime rainfalls at St. Joseph, Mo., April to October, during the 25 years 1910–34*

Years	April		May		June		July		August		September		October	
	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night
	H. m.	*H. m.*	*H. m.*	*H. m.*	*H. m.*	*H. m.*	*H. m.*	*H. m.*	*H. m.*	*H. m.*	*H. m.*	*H. m.*	*H. m.*	*H. m.*
1910	26 46	19 30	68 49	86 56	16 13	7 06	5 51	6 43	22 24	30 56	24 57	30 43	11 19	6 12
1911	17 42	35 33	14 45	28 23	12 53	1 07	13 29	18 12	4 35	16 11	33 06	34 30	24 49	15 27
1912	15 50	20 33	14 33	18 59	22 57	23 00	9 31	11 45	30 48	12 49	18 04	20 14	30 29	22 44
1913	37 02	43 35	39 46	37 16	10 59	21 24	3 57	6 36	4 19	8 20	24 54	36 39	29 44	35 55
1914	20 17	22 48	11 39	3 10	20 51	24 53	12 32	4 50	4 11	14 45	28 59	27 03	29 50	31 30
1915	24 09	18 21	62 20	56 07	20 59	23 13	27 05	34 58	17 51	15 21	37 17	44 35	6 47	13 35
1916	35 19	28 46	34 37	44 02	21 17	37 03	2 56	6 00	16 30	20 29	10 19	24 53	34 26	24 08
1917	70 20	58 40	38 22	20 46	21 40	16 37	3 54	13 36	19 03	16 35	21 30	15 01	18 37	21 01
1918	30 00	45 32	22 55	32 32	8 59	13 37	17 28	14 29	20 25	38 17	19 41	38 52	39 32	34 29
1919	28 08	33 28	18 31	33 41	29 59	24 30	9 08	8 42	13 57	5 37	25 55	37 25	42 46	24 16
1920	50 40	54 56	33 53	21 19	11 56	12 48	9 10	31 13	16 03	19 00	15 18	35 23	20 49	10 53
1921	41 24	20 14	16 48	28 38	24 18	20 42	4 41	11 28	14 55	29 08	30 44	30 26	11 41	17 02
1922	47 15	41 57	49 06	26 50	5 00	10 09	9 40	29 49	7 37	8 24	15 21	25 20	22 26	27 10
1923	23 00	15 37	21 36	33 38	29 39	19 53	11 43	16 10	29 49	32 22	26 36	21 21	37 26	46 05
1924	10 55	15 41	26 55	39 54	15 37	38 42	18 35	16 38	17 36	27 19	27 02	24 03	14 01	12 25
1925	50 38	25 05	21 51	18 07	21 42	37 32	12 58	11 55	13 11	28 39	44 29	52 23	47 12	37 57
1926	36 42	45 57	6 06	22 20	18 00	16 19	11 52	16 38	16 51	18 40	54 38	97 24	32 03	21 35
1927	58 46	74 16	7 17	20 49	38 06	28 09	11 01	17 06	19 54	32 49	12 44	54 28	14 22	23 08
1928	27 42	23 29	19 09	21 08	43 07	42 36	15 36	19 50	17 12	21 36	5 26	25 52	28 21	36 30
1929	40 11	67 32	35 32	42 43	25 00	29 53	14 23	38 37	6 38	34 45	18 43	14 12	45 04	54 15
1930	28 25	44 55	31 15	30 40	16 34	31 04	14 52	5 07	21 45	29 19	21 40	18 54	42 31	40 01
1931	52 09	52 01	49 37	32 53	10 23	8 35	10 23	22 12	29 59	39 45	30 49	23 40	32 43	28 57
1932	36 57	40 32	14 24	22 44	31 18	17 02	15 41	13 21	21 19	21 21	13 19	18 14	23 43	17 18
1933	30 04	24 46	47 47	34 13	6 26	19 48	2 55	18 01	32 06	48 17	28 24	35 57	3 59	8 57
1934	7 47	17 52	9 30	18 21	6 02	16 32	4 06	11 26	23 04	25 08	43 01	57 53	10 57	18 01
Means	33 56	35 40	28 41	31 03	19 36	21 41	10 56	16 13	17 41	23 50	25 19	33 49	26 13	25 11
Percentages	49	51	48	52	47	53	40	60	43	57	43	57	.51	.49

TABLE 4.—*Average duration of rains beginning in the hours indicated for the 25 years 1910–34, at St. Joseph, Mo.*

Month	A. M.												P. M.											
	12-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	Mean
	H. m.	H. m.	H. m.	H. m.	H. m.	H. m.	H. m.	H. m.	H. m.	H. m.	H. m.	H. m.	H. m.	H. m.	H. m.	H. m.	H. m.	H. m.	H. m.	H. m.	H. m.	H. m.	H. m.	H. m.	H. m.
April	4 36	4 00	6 03	3 09	8 13	2 42	3 52	4 48	3 36	3 58	6 56	2 22	4 43	2 48	1 39	4 24	2 36	2 51	3 35	4 03	5 46	8 49	5 24	6 17	4 28
May	5 51	3 04	2 06	5 19	3 35	5 27	2 19	3 00	4 05	4 22	2 08	4 23	1 21	3 41	3 12	3 52	2 58	1 37	1 08	4 54	4 30	7 05	4 51	1 50	3 37
June	2 00	3 49	2 25	2 31	3 04	1 57	2 07	1 58	1 37	2 44	2 07	1 38	2 59	2 16	2 31	2 55	2 48	2 48	1 34	2 56	3 19	6 15	2 44	3 19	2 41
July	4 34	3 03	3 11	1 48	1 54	2 28	2 07	1 26	1 25	0 54	1 31	1 07	1 21	0 52	2 28	1 26	0 49	2 10	1 11	2 11	2 38	2 18	2 40	4 37	2 05
August	4 33	4 02	2 23	4 16	3 18	2 07	2 37	2 16	1 37	2 13	1 53	1 59	2 08	1 17	1 54	1 10	3 47	1 17	3 52	5 19	4 24	3 02	4 36	4 12	2 56
September	5 43	5 59	2 22	3 45	1 42	2 29	2 20	4 19	3 04	2 40	4 25	2 43	1 49	2 39	1 53	1 54	3 40	2 29	4 44	2 58	5 40	8 14	4 56	6 10	3 42
October	5 50	3 36	4 44	4 57	4 25	1 59	4 16	4 59	2 15	4 07	3 27	3 25	5 03	3 28	6 06	1 13	2 59	4 09	2 20	3 37	3 28	5 11	5 39	3 34	3 57
Average	4 44	3 56	3 19	3 41	3 44	2 44	2 48	3 15	2 31	3 00	3 12	2 31	2 46	2 26	2 49	2 25	2 48	2 29	2 38	3 43	4 14	5 51	4 24	4 17	3 21

TABLE 5.—*Average duration of rainfall at St. Joseph, Mo., beginning between 7 p. m. and 7 a. m. and 7 a. m. and 7 p. m., April to October, 1910 to 1934 inclusive*

Month	7 p. m. to 7 a. m.	7 a. m. to 7 p. m.	Month	7 p. m. to 7 a. m.	7 a. m. to 7 p. m.
	H. m.	H. m.		H. m.	H. m.
April	5 14	3 41	September	4 22	3 02
May	4 14	2 59	October	4 16	3 38
June	3 02	2 20			
July	2 47	1 23	Averages	3 57	2 44
August	3 44	2 07			

HEATERS TO PREVENT FROSTING OF THEODOLITE LENSES AT LOW TEMPERATURES

By G. GRIMMINGER

[Weather Bureau, Boston, Mass., July 1936]

When pilot-balloon observations were begun at Little America, Antarctica, in 1934, it was soon found that the formation of frost on the theodolite lenses was going to cause considerable trouble. The frost formation became noticeable at a temperature of about −20° F., increasing in intensity with decreasing temperature. It was due to condensation, on the cold glass, of vapor in the observer's breath and of moisture evaporated from his face, and formed on both the eyepiece and the object lenses.[1] At the beginning of the winter night, with the advent of low temperatures and the use of lanterns, this formation of frost would after several minutes make it impossible to see the lantern attached to the balloon; and the observer would then have to stop observing and scrape the two lenses with a small piece of wood once or twice a minute; this, of course, made it difficult to keep the lantern in the field, and in some cases was responsible for losing the balloon entirely. This same difficulty was also experienced by Sverdrup on the *Maud* Expedition.[2]

To remedy the trouble, two simple but effective heaters were devised. The objective heater consisted simply of a 15-watt electric light bulb. This bulb was placed under the theodolite barrel, with the end of the bulb flush with the object lens; around the bulb and theodolite barrel was then wrapped a single layer of asbestos-covered wire mesh, and around this was wrapped a number of turns or ordinary friction tape. The asbestos-covered wire mesh prevented the bulb from burning the tape, and the tape kept the bulb securely fastened to the barrel of the theodolite and at the same time completely protected it from drift and snow. Leads were run from the bulb socket to our building nearby and tapped into a 110-volt line, the current for which was supplied by a gasoline generator. The heat from the lighted bulb heated the end of the theodolite barrel near the objective, and this in turn heated the lens by conduction, preventing any frost formation whatsoever.

This type of device was too bulky for the eyepiece and would not give the observer an unobstructed view of the theodolite scales; hence a resistance type of heater was used here. It consisted of a piece about three-fourths of an inch long cut from a larger resistance unit found among the electrical equipment and made of resistance wire wound on a ceramic tube. With a little filing of the inside of the tube it was easily made to slip on over the end of the eyepiece with a snug fit after the aperture disk had been removed. Leads were run from this resistor into the building where they were connected to a 6-volt storage battery. Although the ceramic tube was an insulator, it was quite thin and plenty of heat got through it to heat the eye-piece tube which in turn conducted heat to the lens. Although no note was made of the size and number of turns of wire used, the resistance was probably about four ohms. The storage battery was used to operate the timing device and theodolite lighting system as well as the eyepiece heater and had to be charged only two or three times during the year.

Although they were rather crude makeshift affairs, both of these heating devices proved very effective, and no frosting of the lenses was experienced after they were put into use. In cases where a 110-volt current is not available, a resistance heater could also be devised for the object lens and operated with a storage battery.

Experience also proved that a long eyepiece tube was much better than a short one. A small-size type of theodolite which was used for several days was quite unsatisfactory because the shortness of the eyepiece tube brought the observer's face and breath so close to the theodolite scales that they frosted over and became difficult to read after a short time.

[1] Scientific results of the *Maud* Expedition, Vol. 2, Meteorology, Part 1, Discussion by H. U. Sverdrup, p. 41.
[2] Ibid., p. 41.